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A Semi-natural, Manipular Observation Nest for *Exoneura* spp. and Other Allodapine Bees (Hymenoptera: Anthophoridae)

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Abstract.—Details are given for construction and use of an observation nest for allodapine bees. The nest can be made for under U.S. $5.00 per unit using readily available materials and standard tools. Twenty-six colonies of *Exoneura asimillima* Rayment were introduced into such nests in Australia and survived for varying periods. The results of several months of experimentation demonstrate the utility of the design. All major types of behavior were observed through the transparent walls. Vigorous colonies progressed in development. Colony survival is positively correlated with the number of eggs inserted in the starter colony and positively, although insignificantly, correlated with the number of adult females and larvae inserted. Such colonies of *E. asimillima* should be initiated with preexisting nests of at least three females and some brood, including eggs.

Bees of the genus *Exoneura* are the dominant members of the tribe Ceratinini throughout the southern half of Australia and in Tasmania. Together with their allodapine allies (chiefly *Allodape*), they form a highly interesting group of species which display various levels of social organization in the nest. Reviews of allodapine and *Exoneura* biology appear elsewhere (allodapines: Michener, 1971, 1974; Sakagami, 1960; Wilson, 1971; *Exoneura*: Michener, 1965, 1971; Rayment, 1951). Nonparasitic allodapine species excavate tubular nests in pithy twigs, stems, plant galls, or flower stalks. Such nests are relatively easy to locate, collect, and dissect. Females will accept substitute nests and/or nest materials and colonies can be kept and propagated under artificial conditions.

Studies of the nesting biology of these bees are of great value in determining the origin and function of sociality in such species. Various types of nests have been used experimentally. Natural nests in native materials have been collected and displaced without disturbing the integrity of the nest itself (Sugden and Pyke, 1988; Sugden, unpubl.). Nests have also been dissected, modified, and replaced in the field (Rayment, 1951; Sugden, unpubl.) and natural nesting materials have been successfully set out to trap *Exoneura* spp. (Schwarz, 1986; Sugden, 1988). A variety of artificial nest materials have been used in experiments involving colony monitoring. Glass or plastic tubes are sufficient for short term laboratory

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work (Maeta et al., 1985; Michener, 1972; Schwarz et al., 1987; Skaife, 1953a, 1953b). Such artificial tubes allow complete visibility of behavior in the nest, but condensation may become a problem since there is no natural vapor absorbency. [Absorbent paper strips have been inserted in impermeable tubes (Skaife, 1953a).] Also, natural nest excavation is precluded. Preference for certain types of materials is exhibited by some species. A recent study compared the success of several types of nest materials, including natural stems and glass tube variations (Maeta et al., 1985). There remains a need for a nest design which is artificial yet acceptable to allodapine bees for nest building, allows continuous observation of all nest activities, permits vapor flow through the lumen walls, allows natural excavation, and is economical and practical to produce. I present here a design for such a nest and some preliminary results in its use with *Exoneura asimillima* Rayment.

MATERIALS AND METHODS

Construction

Materials.—Table 1 lists parts required to build one nest unit. 1) The foundation of the nest is provided by a balsa block; its dimensions are variable but the thickness must be enough to prevent warping if the ends are exposed to weather (i.e., in a window) and long enough to allow reasonable extension of the nest lumen through pith excavation. Available at model shops. 2) Hardwood strips, used in wooden models, provide retaining rails for the acrylic tubing pieces. Available at model shops. 3) Small diameter acrylic tubing is supplied in 2-m or 6-ft lengths. In the U.S., inside diameters (I.D.) are available in 1⁄16-in. graduations down to 1⁄8 in. Available at plastics supply stores. In Australia, the smallest available I.D. at this writing is 4 mm (Cut-To-Size Plastics, Sydney). This was the diameter used in the study discussed here. Milling the half-tube pieces requires loss of one longitudinal half of each piece (see below). 4) The pith cylinder can be obtained from small segments of natural nesting material or cut out of relatively soft balsa. Ideally, it should be slightly softer than the balsa stock. 5) Optional light-shielding covers can be made from cardboard and aluminum foil. A sanding rod is required to form the lumen groove (see below). A 1⁄8-in. brass rod is ideal. Available at model shops for U.S. $0.40 (not included in Table 1). All materials are readily available in the U.S. and in Australia at this writing.

Milling.—Cut the balsa stock to desired dimensions. *Exoneura asimillima* females may excavate several millimeters per day and natural nests may reach 0.7 m (Sugden, in prep.), so length of the balsa block must reflect possible final length of the nest lumen. A 1.0-mm-deep "V"-shaped groove is cut down the length of the block using a straight edge and a sharp knife. This acts as a guide for sanding the rounded channel. A layer of fine grit sandpaper is wrapped around a 1⁄8-in. sanding rod and held tight while rubbing the assembly up and down the groove. A semi-circular cross section will result as the flat edges of the groove are rounded. The thickness of the sandpaper must be accounted for in arriving at the final lumen diameter. Attempts to cut a groove with power tools have met with little success because proper bits are not available. An improvisation made from the circular-ground end of a conventional router bit was tried, but tended to shred the balsa, leaving ragged lumen walls. A smooth-walled lumen is requisite, which also approximates the diameter of the naturally-excavated space of the bee species to be introduced to the unit.

Table 1. Parts required for one observation nest unit, dimensions, and costs in U.S. dollars. Price for metric diameter acrylic tubing converted from Australian to U.S. dollars, November 1987. (U.S. cost approx. $0.14/ft.) Notes addressed in text under Materials (M) or Assembly (A).

Part	Dimensions (mm)	Number/amount	Cost per nest unit	Source, notes
Balsa block	2.5 × 7.6 × 305	1	$1.90	M
Wooden strips	1.6 × 1.6 × 305	2	0.32	M
Acrylic tubing	6 (O.D.) × 4 (I.D.) × 305	2	1.14	M
120 grit sandpaper	—	1 sheet	0.37	M
Pith cylinder plug	4 (O.D.) × 100	1	—	M
Aluminum foil	305 × 500	1	0.05	M
Cardboard	850 × 300	1	—	M
Wood glue	—	1 ml	0.09	A
No. 4 brass wood screws	—	12	0.73	A
Small rubber bands	—	3	0.03	A
Total			$4.63	

Acrylic tubing should match the rounded channel in the balsa wood in its inside diameter. Commercial longitudinal cutting of the tubing by the distributor was not available at the time of this writing due to the small diameter. However, with care, the necessary work can be done in a wood shop with standard tools. A jig is necessary to hold the pieces while being ripped and sanded. This is made by cutting a groove in a piece of hardwood about 10 × 3 × 30 cm. The groove should be one full outside diameter (O.D.) wide and ½ O.D. deep, a snug fit for the acrylic tubing. One end of the groove is blocked off by nailing an end piece to the wood. Cut the acrylic tubing into 15–20-cm lengths. Place one into the jig groove. The fine-toothed blade of a band saw can then rip the length of the tubing, using the face of the jig as a guide. The resulting jig-held piece should be slightly more than a half-diameter. The assembly is then inverted over a fixed belt sander to smooth the edges of the band saw cut. The acrylic tubing must fit tightly enough in the groove of the jig to remain in place as it is lowered onto the sander. The belt should only graze the face of the jig in smoothing the edges of the tubing.

Removed from the jig, the half-diameter length of tubing can be cut sagittally into segments on the band saw. The ends are squared and smoothed on a disk sander, with burrs removed by hand with fine grit sandpaper. Optionally, small sleeves can be attached to the interior of the tubing ends to integrate the assembled tubing pieces and baffle the joints (Fig. 1f). They are made from small rectangles of thin acetate or acrylic film and set with a quick-dry adhesive such as Super Glue.

Basal pith plugs can be cut as square-end blanks from natural nesting materials and rounded into cylinders with sandpaper. Also, soft pith can be pushed or bored out of stems (Maeta et al., 1985). Especially soft pieces of balsa may substitute.

Assembly.—A complete nest unit is illustrated in Figure 1. Glue the wood strips with sparing amounts of white glue along either side of the half-lumen groove, leaving a 1-mm or $\frac{1}{16}$-in. "shoulder" on which the acrylic half-diameter pieces will rest. Use a piece of cut tubing as a guide. The tubing should fit snugly between the glued strips but loosely enough to allow easy removal. Determine the lengths of the tubing pieces to be used and make leader holes along the side of the wood base for screws corresponding to the center of each piece of tubing. Place a droplet

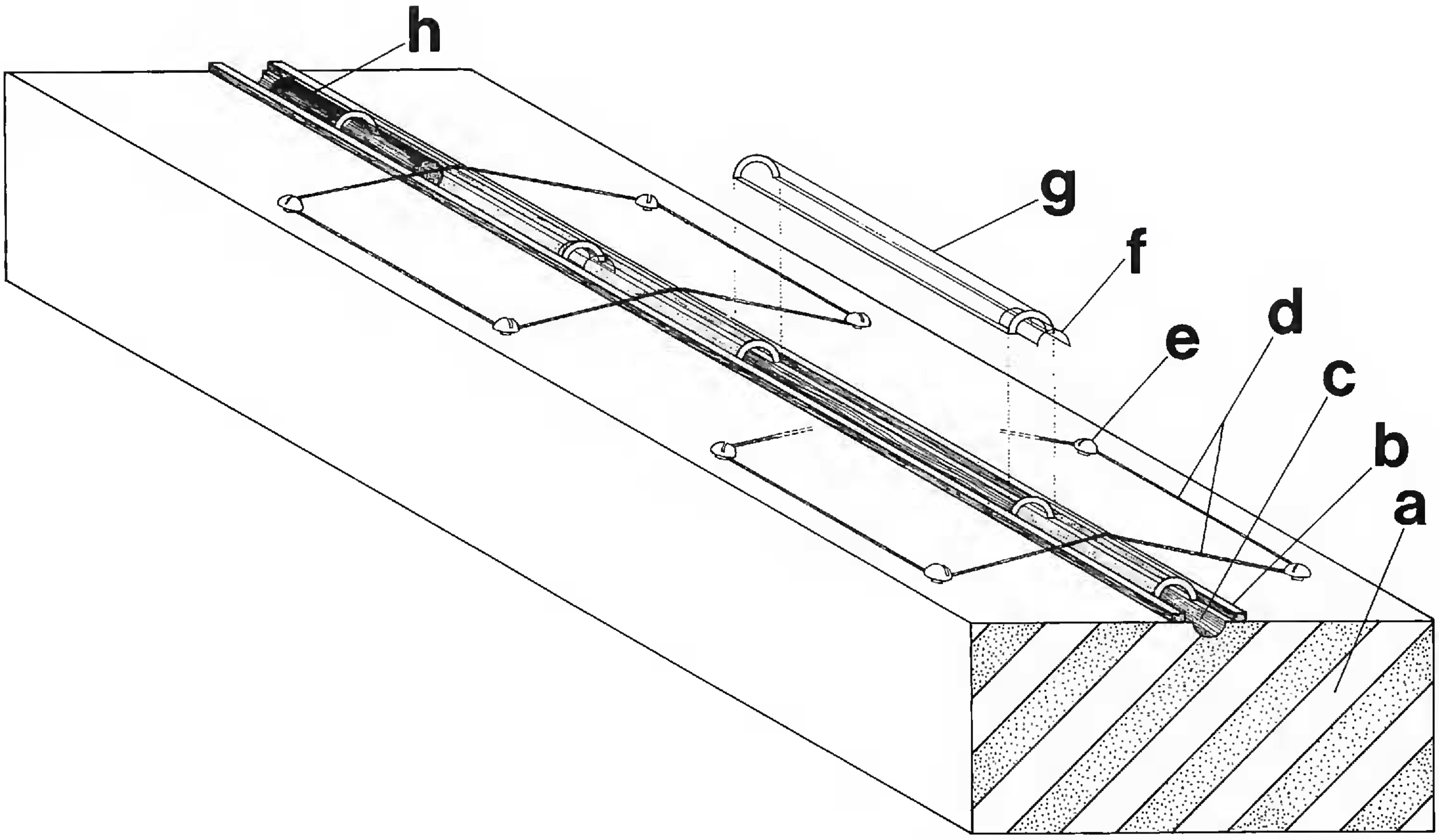

Figure 1. Assembled nest unit, to scale (see Table 1). a. Orientation-facilitating pattern. b. Wooden strip retainer. c. Pre-lumen space or "runway." d. Rubber band as tubing brace. e. Brass screw as rubber band cleat. f. Tubing section sleeve or baffle. g. Acrylic half-tube lumen piece. h. Pith plug.

of glue in each leader hole before inserting screw. The glue will prevent the screws from working loose in the soft balsa while under tension. Leave 1–2 mm of screw shank above the surface level of the block as rubber band anchor points.

Set the tubing lengths in place. Plan to have the entrance piece stationary, as the bees will make a permanent adhering collar of wood fragments a few millimeters inside the lumen or flush with the entrance. It is useful, although not necessary, to have the end of this first piece set back from the face of the balsa block by a few millimeters. This allows the bees a "runway" and often it catches interesting debris ejected from the lumen by the bees. Insert the pith cylinder several centimeters into the basal piece of tubing. Allow enough covered length for rapid excavation by vigorous colonies. (See Results for excavation rates.) Extra plug length should be left to either push into the existing lumen or to extend the lumen over as the pith is chewed up. The tubing pieces should fit snugly together, leaving no gaps between them. Small cracks will be plugged by the bees. Stretch rubber bands between the screws to apply downward tension on the tubing. The entrance end of the wooden base can be patterned to assist free-flying bees in orienting to their nest.

Introduction of Bees

Adult bees can be inserted individually through the nest entrance or into the lumen by removing a segment of tubing. Use cotton wool to plug the lumen from escaping bees during and after introduction. Cotton swabs cut in half and fluffed to fit make convenient stoppers. Allow one or more days for the bees to adapt before removing the cotton wool. They may tear at it and pass little balls of fiber down the lumen in attempts to dig out. Position nest (if free flight desired). Remove plug.

Bees can be kept enclosed in the nest for weeks or months or they may be allowed to fly freely from a nest position at a window in the lab. Observe under low light conditions; keep the nest covered when not under observation and do not expose to sunlight.

Enclosed bees can be fed honey or sugar solution from a pipette (Schwarz et al., 1987; Sugden, unpubl.) and larvae will consume honey bee-collected pollen moistened with dilute honey (Rayment, 1951; Sugden, unpubl.).

RESULTS

The tests described here were carried out at Nadgee Reserve, southeastern coastal New South Wales. Natural nests of *Exoneura asimillima* used to stock the artificial nests were collected from sites 10 and 17 km distant from the Laboratory [described in Sugden and Pyke (1988)].

Four nest units were constructed and bees introduced from natural nests on 17 October 1986. Between mid-October and 14 January 1987, 22 more colonies were initiated. New colonies were continuously selected to replace those which died before the end of observations. A total of 26 colonies of *Exoneura asimillima* were introduced into 12 nest units. Nests were kept in an unheated room and allowed free flight into the open environment or a flight cage (8–19 January 1987) through louvered windows. Populations were censused and colony attrition recorded. Observations extended through 13 April 1987.

Population and survival data are displayed in Table 2. Survival of a colony is defined as the number of days the nest is continuously occupied by at least one adult female. Among the 26 colonies used in the study, four received supplemental additions of immature bees and eight (including one of the latter) survived for less than 2 days for various reasons. These 11 colonies are not considered in the analysis below. Of the remaining, survival was positively correlated with number of eggs initially inserted into the nest ($r = 0.5898$; $0.05 > \alpha < 0.01$; $n = 15$), although the data are minimal. The number of adult females and larvae inserted were positively, but not significantly correlated with survival. Square root transformation of the data and re-analysis produced equivalent results. It is interesting to note that, from the entire sample, nests which were started with only one or two adult females did not survive beyond 17 days and 50% of these ($n = 12$) died out after the first day. Two of three colonies in which eggs were produced contained three adult females at nest initiation and survived beyond the mean number of days for nests lasting longer than 1 day. The colony producing three eggs had the second longest survival of any colony, however survival was undoubtedly influenced by the large number of adults which eclosed from inserted pupae.

A number of photographs of bee activity were taken through the acrylic tubing. Detailed photographic monitoring was possible through the transparent wall. Image resolution is only slightly blurred; the tubing joints and rubber bands obscure some of the view of the nest.

The full range of *Exoneura* nest behavior was observed in the nests, including exit and return of foragers, trophalaxis between adults, provisioning of brood, entrance guarding, excavation and pith collar construction, individual development from egg to pupal eclosion, and male transfer between nests. Some of these observations will be described in more detail elsewhere (Sugden, in prep.)

Mean pith plug excavation rates ranged from 0.0 to 2.4 mm per day. In five cases, the basal pith plugs were of a harder consistency than the balsa and the

Table 2. Data from *Exoneura asimillima* colonies. Bee data represent numbers of individuals originally inserted into nests. Numbers in parentheses represent eggs produced by colonies while in confinement. Subscript 1: all data except nests supplemented with individual bees after initial establishment; subscript 2: same data except cases where Survival = 1.

Colony number	Survival (days)	Eggs	Larvae	Pupae	Adult females	Adult males
1	163	6	15	0	3	0
2	1	8	2	0	1	0
4	1	2	6	0	1	0
5	1	0	9	0	1	0
8	9	1	13	1	3	0
9	113	(3) 2	1	24	3	0
10	92	1	1	6	4	0
11	16	1	0	0	3	0
12	6	4	2	0	2	0
13	48	0	0	1	8	5
14	90	0	0	0	5	0
15	17	0	0	0	1	0
16	8	0	1	3	1	0
17	1	0	0	3	1	0
18	6	(1) 0	4	5	1	0
19	76	(1) 2	8	1	3	0
20	1	2	0	0	1	0
21	8	0	2	8	1	0
22	74	2	4	5	9	2
23	1	6	1	0	3	0
24	3	0	0	0	2	0
25	1	4	0	0	2	6
$n_1 = 22$	$\text{Mean}_1 = 33.45$	1.86	3.14	2.59	2.68	0.59
$n_2 = 15$	$\text{Mean}_2 = 48.60$	1.27	3.40	3.60	3.27	0.47

bees excavated downward into the balsa base. This made manipular access and observation impossible. Cracks in tubing joints were filled with pith particles by bees from vigorous colonies but not always by small colonies. The rubber bands deteriorated rapidly, requiring replacement after 1 or 2 mo. A custom made gable protruding out of the window protected the nest entrances from rain. The cardboard and aluminum foil covers worked well in protecting the nests from light. Ants were not implicated in the demise of any sound nests, although the remains of bees in one dead colony were carried off by workers of *Iridomyrmex* sp. *Iridomyrmex glaber* and other species of this genus are apparently major predators of *Exoneura* under natural conditions (Rayment, 1951; Sugden, in prep.). Skaife (1953a) mentions *I. humilis* as a nuisance with regard to captive *Allodape* colonies in Southern Africa.

Discussion

The design presented here successfully simulates natural nest structure. It allows vapor flow through lumen walls, free excavation of natural pith material in lumen extension by the bees, and continuous unobstructed observation and photography. The bee colony can be freely manipulated, construction is simple with standard tools, materials are readily available, and the cost per unit is small.

The tests discussed above were done during the middle and late seasons of activity for *Exoneura asimillima,* when the age distribution of natural colonies is shifting toward adults and when less vigorous colonies are dying. Greater colony growth and perhaps lower colony mortality would have occurred if the artificial colonies had been started earlier in the season. Despite this, it is obvious that colony survival following insertion into the artificial nest is dependent on the size of the population of the initiating colony. Some eggs and a minimum of 3 adult females from preexisting nests give the best assurance of prolonged colony survival.

One possible shortcoming of this design is that it requires the insertion of preestablished colonies. The artificial nests were not tested to see whether they would be selected by free-flying foundress females, but given their apparent preference for natural materials (Sakagami et al., 1985; Sugden, in prep.), this seems unlikely. [However, Skaife (1953a) coaxed foundresses of African *Allodape* spp. to select artificial nests.] Certain reversible modifications of the observation nest entrance such as the attachment of pieces of predrilled natural nest material might be more conducive to nest establishment by foundresses. This was not tried.

It is not known whether other species of *Exoneura* or *Allodape* would accept the observation nest described here, although it seems highly probable, based on similarities in nest biologies of most allodapines.

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